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Spatio-temporal development of the diffuse barrier discharge in nitrogen

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Results of spatio-temporally resolved optical emission spectroscopy of the diffuse dielectric barrier discharge in nitrogen are presented and compared with results of numerical modelling. The model is taking into account the surface processes and involves the special electrode geometry used in the experiment.

1. Introduction

Within the last few years diffuse barrier discharges (BD) often referred to as homogeneous BD or as atmospheric pressure glow discharges (APGD) became an object of intensive experimental and theoretical investigations [1]. The diffuse BD in nitrogen has been investigated by means of voltage-current oscillography, short exposure time photography, optical emission spectroscopy (OES) [2, 6] as well as numerical modelling [3, 4].

The criterion to generate a diffuse BD is the presence of carrier charges at a low electric field, i.e. a memory effect responsible for the production of primary electrons below a voltage leading to filament formation. Several processes has been discussed as Penning ionisation due to metastable collisions [3] or electron desorption from the dielectric surface [4]. In these contribution results of spatio-temporally resolved emission spectroscopy are presented and compared with results of numerical modelling including the surface processes.

2. Experimental technique

Diffuse BD generated in pure flowing nitrogen and a discharge gap of 1.0 mm was investigated with a modified experimental set-up already used for diagnostics of filamentary barrier discharges [5, 6]. Especially the same semi-spherical electrodes (thickness of the glass was 1.5 mm) were used (see figure 1a). Due to the combined action of a single photon counting device and an electrically triggered pattern generator time resolution of 2.3 μ s has been archived. The spatial resolution along the discharge axis was 0.2 mm by using stepper motor controlled imaging optics.

3. Model

The model of the diffuse BD was based on the system of fluid equations coupled with the Poisson equation. The details of the model and the solution method can be found in [4].

Special attention was paid to the influence of the electrode geometry. To simulate qualitatively small deviations from plane geometry, electrodes were divided into radial pieces (see figure 1b), and the axial electric field was assumed to be dependent on the radius.

The densities of excited states $A^3S_u^+$ and $C^3\pi_u$ of nitrogen were calculated on the basis of the corresponding balance equations. Since the lifetime of the metastable state is determined by the frequency of quenching by impurity (NO) atoms, this lifetime was chosen arbitrarily ($3 \cdot 10^4$ s⁻¹) in order to fit the experimental results.

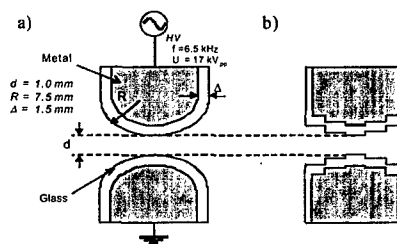


Figure 1: Electrode arrangement used in the experiment (a) and in the model (b)

4. Results and discussion

The emission spectrum of the diffuse BD in nitrogen consists of the second positive system of nitrogen (SPS), NO γ -bands and band of ON $_2$ -excimer at 557 nm [2]. For 0-0 transition of the SPS and 0-3 transition of NO γ the spatio-temporally resolved intensity distributions are shown in figure 2. In the pictures the time scale slightly exceeds the period of the driving voltage ($1/T = 1/6.5$ kHz = 153 μ s) and the upper electrode is the cathode within the first half period. The intensity is coded in grey-scale in logarithmic steps. The calculated density of the N $_2$ (C)-molecules is shown in figure 3a. Since the effective life times of the excited states are orders of magnitude smaller than the characteristic time scales for density evolution, the pictures 2a and 3a can be compared directly. Furthermore it is known that the excitation of the NO(A) state is dominated by N $_2$ -metastable collisions [2, 6]. Therefore the calculated densities of the N $_2$ (A)-densities is shown in figure 3b and can be directly compared with the NO γ -signal. All intensity distributions as well as density profiles shows the maximum near the momentarily anode. The SPS respectively the N $_2$ (C)-density growths exponentially towards the anode and between the two half widths no signal is seen. Since the N $_2$ (C) excitation is initiated by electrons [2] this demonstrates that the

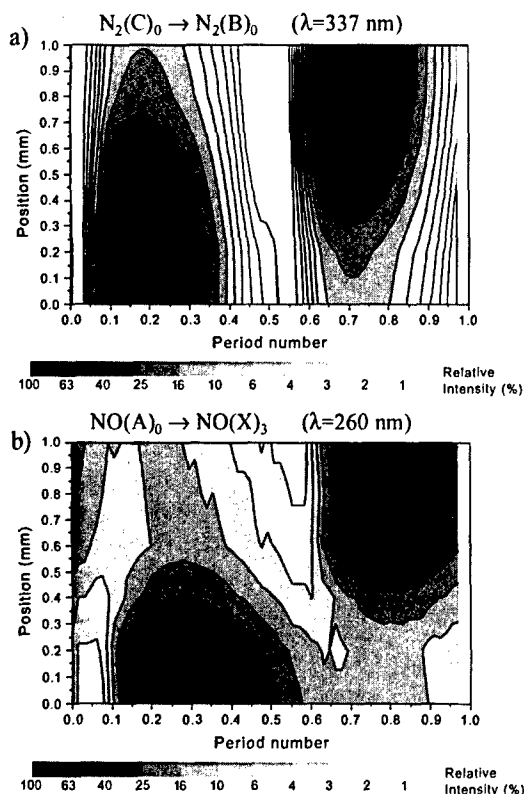


Figure 2: Results of spatio-temporally resolved OES

diffuse BD in nitrogen is a Townsend-like discharge, i.e. no large space charges distorting the electric field are produced and finally an exponential growth of the electron current towards the anode is observed. The NO_γ signal resp. $NO(A)$ -density distribution is delayed against the SPS resp. $N_2(C)$ and both profiles shows a similar slower decay. A better correspondence of the measured SPS intensities with numerical modelling results of $N_2(C)$ density than in previous simulations is obtained [6]. There the surface processes and the special electrode contour had not been considered. This result points out the importance of the electron desorption process from the cathode (i.e. the previous anode). A similar good qualitative agreement was observed for measured and calculated discharge current. In planned experiments a plane parallel discharge cell will be used to investigate the influence of surface contour in more detail.

5. Conclusion

A general qualitative agreement between experiment and model is observed, referring to the importance of surface processes, in particular electron desorption from the cathode. Future experimental investigations will be dedicated to a planar electrode geometry in order to have a better comparability with the numerical modelling results.

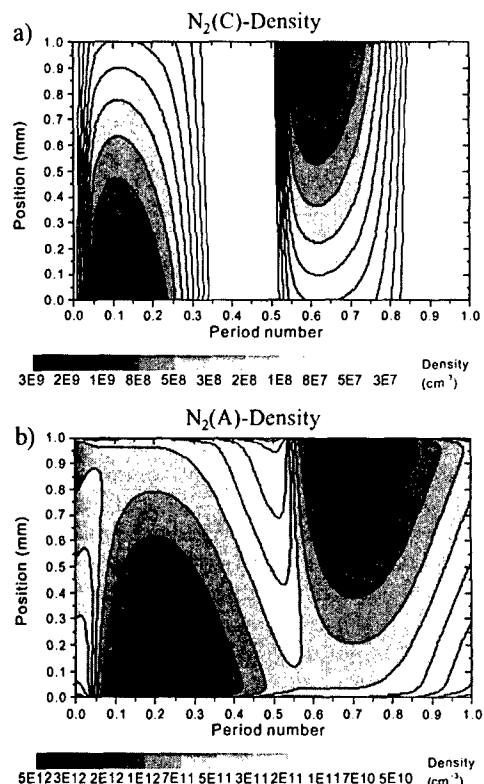


Figure 3: Results of numerical modelling

6. Acknowledgements

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